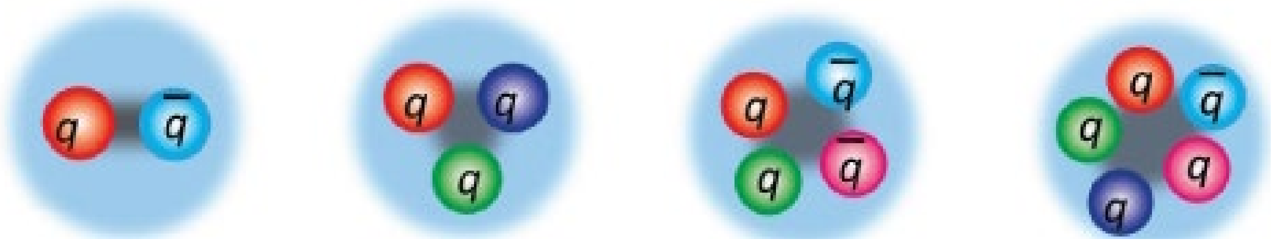
ESTRUCTURA QUARK-GLUON DE LA MATERIA



VNIVERSITAT DE VALÈNCIA

IFIC
INSTITUT DE FÍSICA CORPUSCULAR

EXCELENCIA SEVERO OCHOA

FÍSICA HADRÓNICA, INTERACCIONES FUNDAMENTALES Y FÍSICA NUCLEAR

PROYECTO : FPA2016-77177-C2-1-P (Coordinado)

COMPONENTES DEL GRUPO

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M. Rinaldi : Contratado Proyecto, CSIC

R. Bruschini : Contrato Predoctoral (FPI), CSIC

TEMAS GENERALES DE INVESTIGACIÓN Y COLABORACIONES

Estructura Hadrónica

V. Vento , S. Noguera, P. González, J. Vijande, V. Pagura, M. Rinaldi, R. Bruschini

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Università degli Studi di Peruggia (Italia) (S. Scopetta)
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Universidad Nacional de La Plata (Argentina) (C. García Canal, D. Gómez Dumm)
CONICET (Argentina) (T. Tarutina)
Laboratorio TANDAR (Argentina) (N. Scoccola)
Instituto Politécnico Nacional (Méjico) (A. Courtois, H. Garcilazo)
Chungnam National University (Corea del Sur) (B-J. Park)
Chungbuk National University (Corea del Sur) (H-J. Lee)

Monopolos Magnéticos

V. Vento

Universidad Nacional de La Plata (C. García Canal, L. Epele, H. Fanchioti)
MoEDAL (CERN)

RESEARCH

1. Hadron distribution functions

Constituent Quark Models, Light Front Formalism and AdS/QCD (V. Vento, M. Rinaldi)
Nambu Jona Lasinio Models (S. Noguera)

2. Non standard hadrons

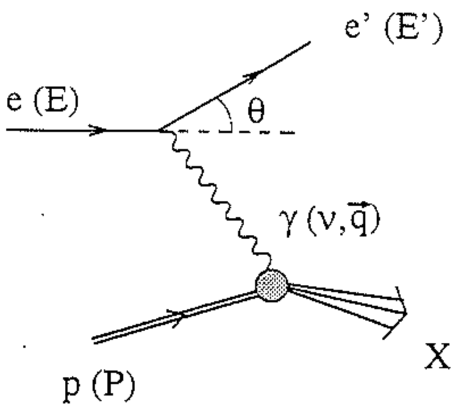
Glueballs from AdS/QCD (V. Vento, M. Rinaldi)
Unconventional heavy quarkonia and hybrids from Constituent Quark Models (P. González, R. Bruschini)
Multiquark states from Constituent Quark Models (J. Vijande)

3. Magnetic fields in nonlocal chiral quark models (S. Noguera, V. Pagura)

4. Magnetic monopoles (V. Vento)

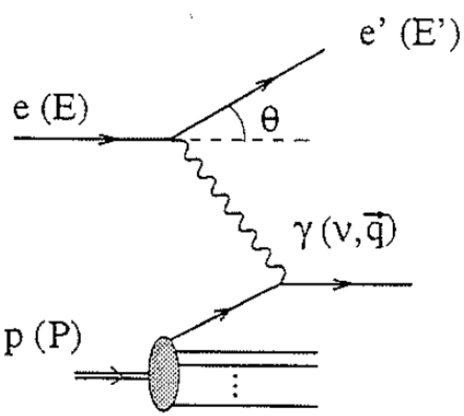
1. Hadron Distribution Functions

Partonic model description at Q0**2 + Perturbative QCD evolution to Q**2



$$\frac{d^2\sigma}{d\Omega\, dE'} = \frac{\alpha^2}{4E^2 \sin^4 \frac{\theta}{4}} \left(2W_1(\nu, Q^2) \sin^2 \frac{\theta}{2} + W_2(\nu, Q^2) \cos^2 \frac{\theta}{2}\right)$$

$$Q^2 \to \infty, \nu \to \infty: \quad \begin{array}{ccc} MW_1 & \to & F_1(x) \\ \nu W_2 & \to & F_2(x) \end{array} \quad x \equiv \frac{Q^2}{2M\nu} = \frac{Q^2}{2Pq}$$



$$F_2(x) = \sum_i e_i^2 x f_i(x)$$

NRQM for the proton at Q0**2

$$F_2^p(x,Q_0^2) = e_u^2 x u_v^p(x,Q_0^2) + e_d^2 x d_v^p(x,Q_0^2)$$

$$x q_v(x) = x \int d\vec{p}\, n_v(\vec{p})\delta\left(x - \frac{pq}{Pq}\right)$$

$$n_{u,\,d}(\vec{p}) = \langle \text{protón} | \sum_{i=1}^{3} \frac{1 \pm \tau_z^{(i)}}{2} \delta(\vec{p}_i - \vec{p}) | \text{protón} \rangle$$

Example: Harmonic oscillator potential $n_i(\vec{p}) \equiv n_i(p)$

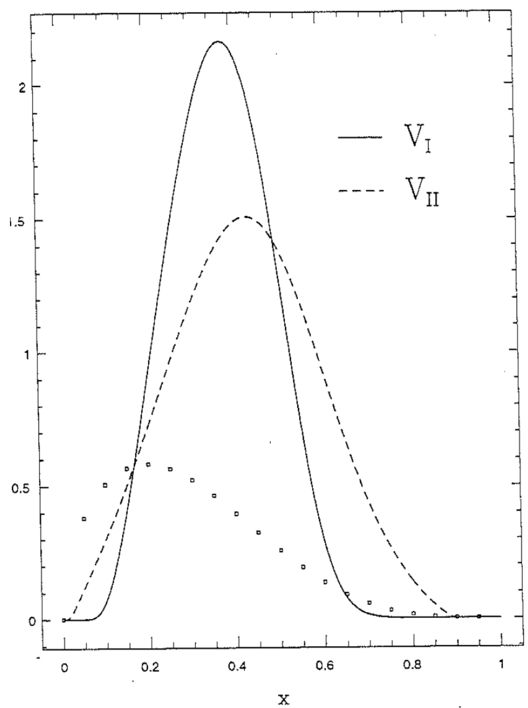
$$n_u(p) = 2n_d(p) = \frac{2}{\alpha^3 \pi^{3/2}} \left(\frac{3}{2}\right)^{3/2} \exp\left(-\frac{3p^2}{2\alpha^2}\right)$$

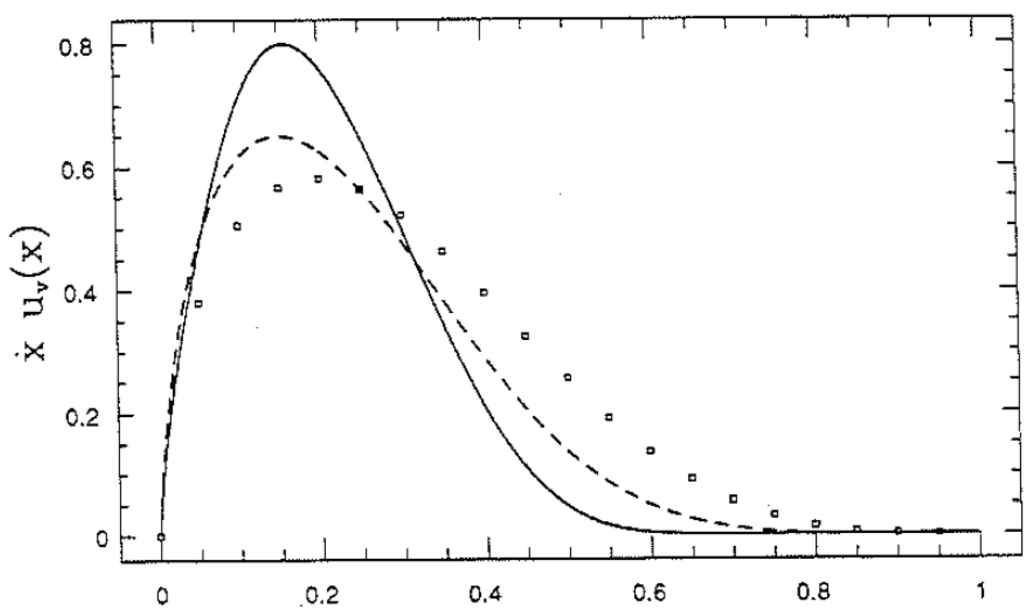
QCD Evolution

$$\langle \mathcal{O}(Q^2)\rangle_n = \int dx\, x^{n-2}\mathcal{O}(x,Q^2)$$

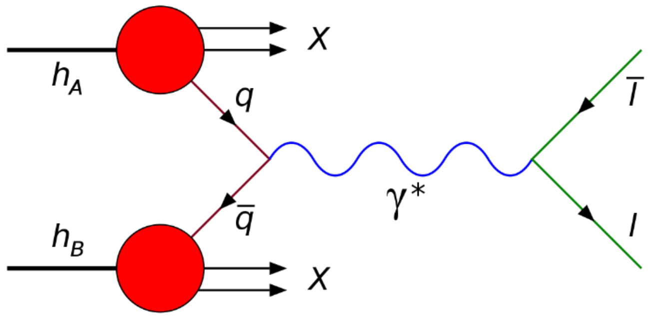
$$L_0 \equiv \frac{\ln\left(\frac{Q^2}{\Lambda^2}\right)}{\ln\left(\frac{Q_0^2}{\Lambda^2}\right)}$$

$$\begin{aligned}
\langle xu_v(Q^2)\rangle_n &= \langle xu_v(Q_0^2)\rangle_n L_0^{-a_{NS}(n)} \\
\langle xd_v(Q^2)\rangle_n &= \langle xd_v(Q_0^2)\rangle_n L_0^{-a_{NS}(n)} \\
\langle x\xi(Q^2)\rangle_n &= \frac{1}{6}\langle xu_v(Q_0^2) + xd_v(Q_0^2)\rangle_n \\
&\quad \left[\alpha_n L_0^{-a_-(n)} + (1-\alpha_n)L_0^{-a_+(n)} - L_0^{-a_{NS}(n)}\right] \\
\langle xG(Q^2)\rangle_n &= \langle xu_v(Q_0^2) + xd_v(Q_0^2)\rangle_n (1-\alpha_n)\frac{\alpha_n}{\beta_n}\left[L_0^{-a_-(n)} - L_0^{-a_+(n)}\right]
\end{aligned}$$





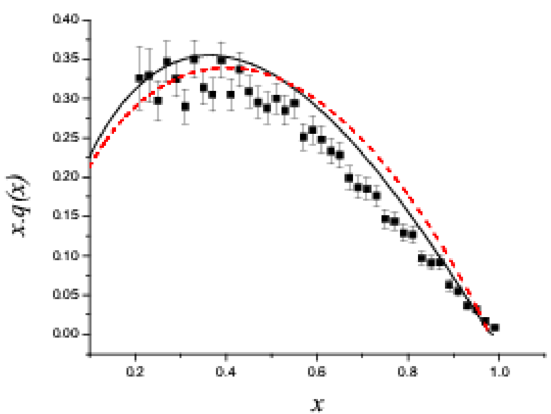
Pion Nucleus Drell Yan process

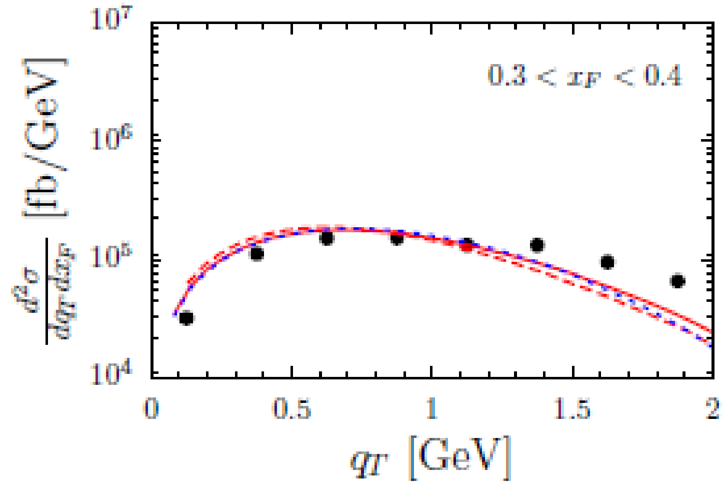


DY pair production in pion–nucleus scattering is a unique probe of pion parton distribution functions

Large Q**2 and transverse momentum

$$\frac{d\sigma}{dq_T^2 d\tau dy} = \sum_{a,b} \sigma_{q\bar{q}}^{(LO)} \int_0^\infty db \frac{b}{2} J_0(b\, q_T)\, S_q(Q,b)\, S_{NP}^{h_1 h_2}(b) \cdot \left[(f_{a/h_1} \otimes C_{qa}) \left(x_1, \frac{b_0^2}{b^2}\right) (f_{b/h_2} \otimes C_{\bar{q}b}) \left(x_2, \frac{b_0^2}{b^2}\right) + q \leftrightarrow \bar{q} \right]$$



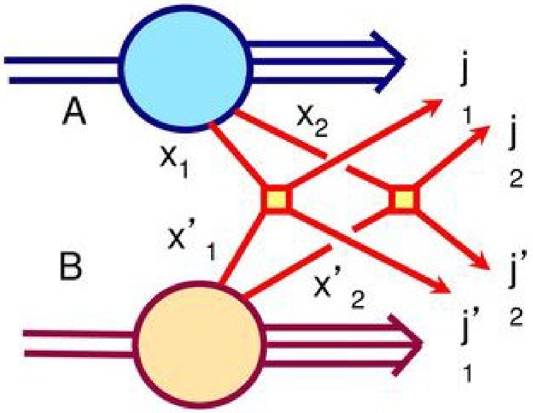


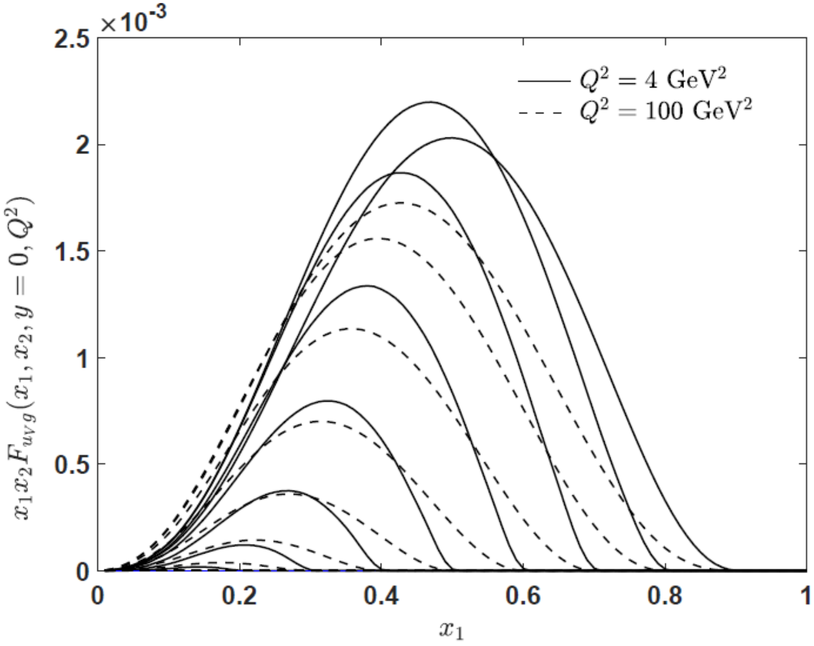
F. A. Ceccopieri, A. Courtoy, S. Noguera, S. Scopetta   Eur. Phys. J. C78, 644 (2018)

Double parton distribution functions

A, B: Pion

$$\bar{F}_{u\bar{d}}(x_1, x_2, y, Q^2)$$





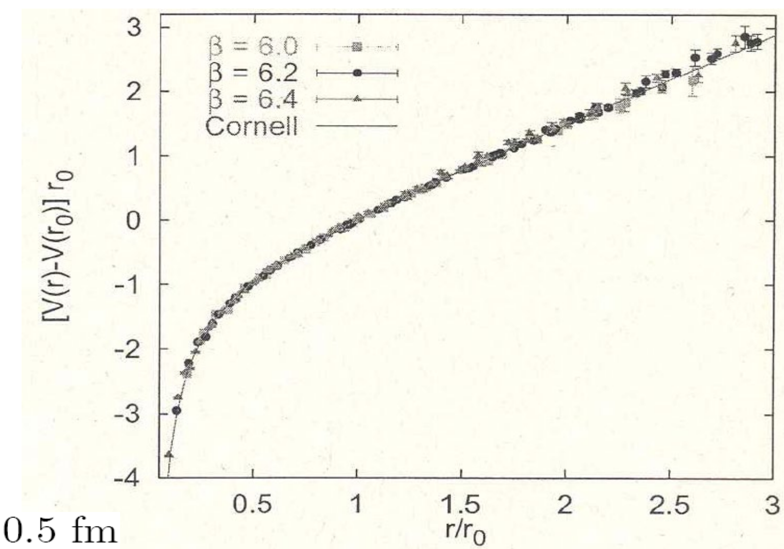
M. Rinaldi, S. Scopetta, M. Traini, V. Vento Eur. Phys. J. C78, 781 (2018)

2. Non Standard Hadrons

Since 2003 experimental signals of nonstandard hadrons

Born-Oppenheimer potentials from Lattice

Static potential from quenched Lattice – QCD (Born-Oppenheimer approximation)

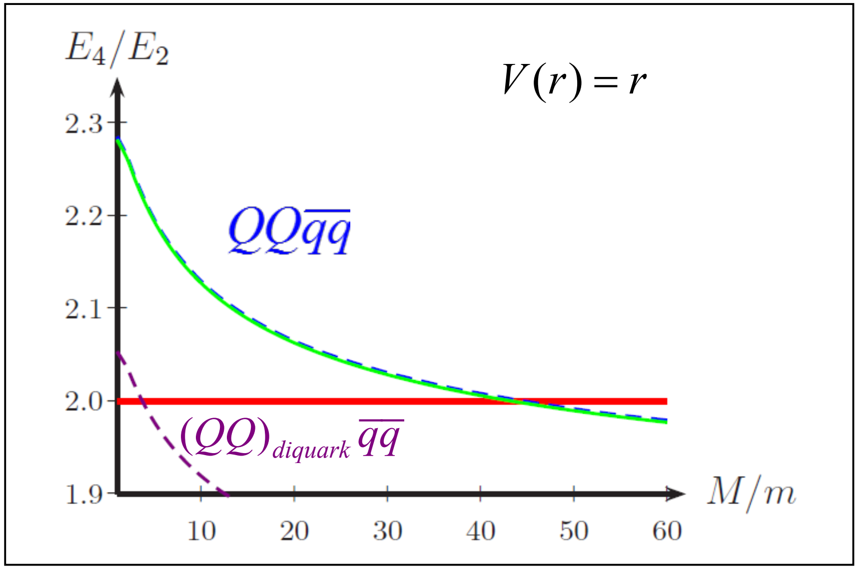


$r_0 \approx 0.5$ fm

$$V_{st}(r) = \sigma\, r - \frac{\kappa}{r} + C$$

Multiquarks

Diquarks (antisymmetric in color and spin) imply overbinding: too many tetraquarks



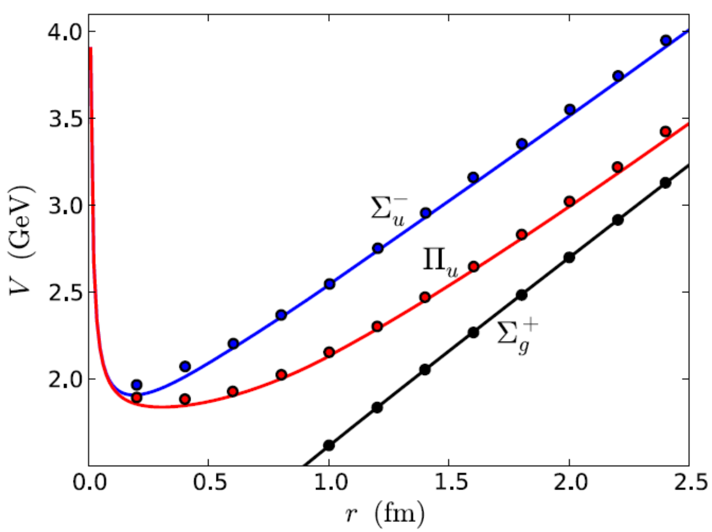
J. M. Richard, A. Valcarce, J. Vijande Phys. Rev. C97, 035211 (2018)

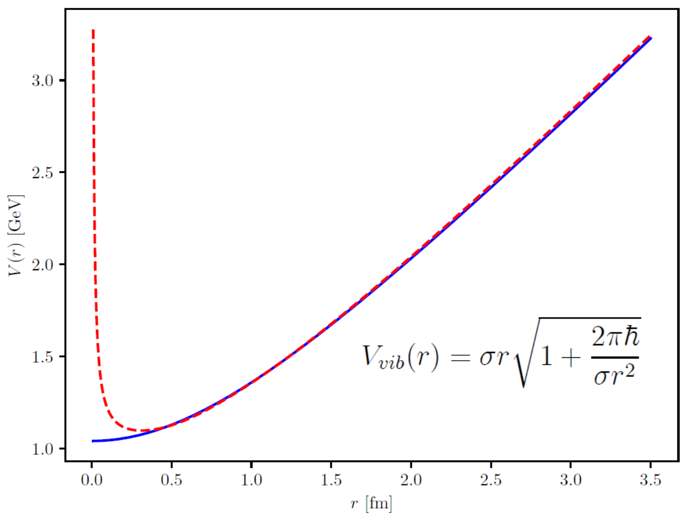
Quarkonium Hybrid Mesons $(Q\bar{Q})_8 + g$

Energy levels of $Q\bar{Q}$ in the excited flavor singlet BO potentials

Hybrid potentials from quenched Lattice – QCD : Π_u , Σ_u^- , …

Π_u can be identified with V_{vib}





1^{--} Bottomonium

$b\bar{b}$ Schrödinger equation with $V_{st}(r)$

nl States	M_{nl} (MeV)	M_{PDG} (MeV)
$1s$	9463	9460.30 ± 0.26
$2s$	10023	10023.26 ± 0.31
$1d$	10169	10163.7 ± 1.4
$3s$	10358	10355.2 ± 0.5
$2d$	10455	
$4s$	10628	10579.4 ± 1.2
$3d$	10703	
$5s$ ($\Upsilon(5s)$)	10865	
$\Upsilon(10860)$		$10889.9^{+3.2}_{-2.6}$

$b\bar{b}_8 + g$ Schrödinger equation with $V_{vib}(r)$

1p	10888 MeV	$H(10888)$
2p	11082 MeV	
3p	11267 MeV	
…	…	

Is there any experimental signature of $H(10888)$?

Data: $\Upsilon(10860)$ with the same rates for decaying to $\pi^+\pi^- h_b(np)$ and $\pi^+\pi^-\Upsilon(n_f s)$

$$H(10888) \longrightarrow \pi^+\pi^- h_b(np)$$

HQSS ➡

$$\Upsilon(5s) \rightarrow \pi^+\pi^-\Upsilon(n_f s)$$

Proposal: $\Upsilon(10860)$ is a mixed state of $\Upsilon(5s)$ and $H(10888)$

R. Bruschini, P. González arXiv:1811.08236

4. Magnetic monopoles

Ion-monopole cross section is large but background from conventional scatterers hides the ion-monopole signal.

Rutherford backscattering technique

Scan the target with an ion beam whose atomic number is greater than any atomic number in the target leads to no background in a large angular region in the backward direction and therefore a clear signal of monopoles can be obtained.

V. Vento Universe 4, 117 (2018)

FUTURO INMEDIATO

Hadron distributions from Quark Models (NRQM, NJL), Light Front Formalism and AdS/CFT

V. Vento, S. Noguera

Hybrid states in the charmonium spectrum. Quark Model description of Psi (4260).

R. Bruschini, P. González

Multiquark states (tetraquarks, pentaquarks, hexaquarks)

J. Vijande

Magnetic fields in a nonlocal chiral quark model

S. Noguera

Monopole detection

V. Vento

FIN

3. Magnetic field in nonlocal chiral quark model

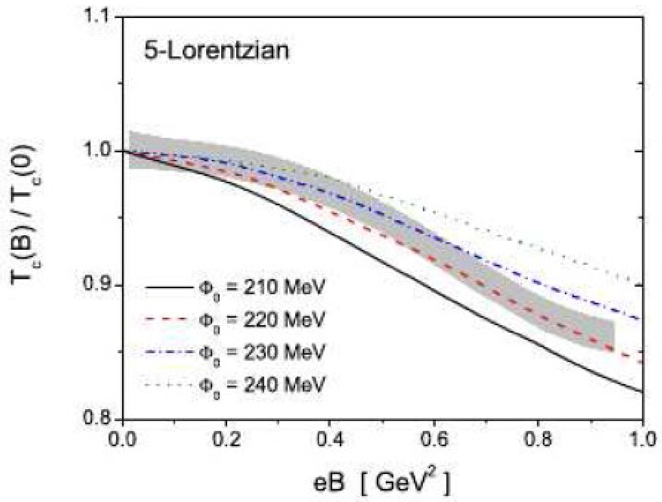
$$\mathcal{L} = \bar{\psi}(i\partial\!\!\!/ - m_0)\psi + G\left[(\bar{\psi}\psi)^2 + (\bar{\psi}i\gamma_5\psi)^2\right]$$

$$\mathcal{L} = \bar{\psi}(x)\left(-i\partial\!\!\!/ + m_c\right)\psi(x) - \frac{G}{2} j_a(x) j_a(x)$$

$$j_a(x) = \int d^4z\, \mathcal{G}(z)\, \bar{\psi}(x + \frac{z}{2})\, \Gamma_a\, \psi(x - \frac{z}{2}) \qquad \Gamma_a = (\mathbb{1}, i\gamma_5\vec{\tau})$$

Minimal coupling: $\partial_\mu \to \partial_\mu - i\,\hat{Q}\mathcal{A}_\mu(x)$ $\qquad \psi(x - z/2) \to W(x, x - z/2)\ \psi(x - z/2)$

Inverse Magnetic Catalysis (IMC) from non-local Nambu-Jona-Lasinio model : Decrease of the critical chiral restoration temperature T_c due to an external magnetic field B.



Φ_0 : quark condensate at zero temperature and zero magnetic field.

Grey band: lattice data

V.P. Pagura, D. Gomez Dumm, S. Noguera, N.N. Scoccola Phys. Rev. D95 (2017) 034013.